



# RESEARCH & TECHNOLOGY

SC15 Energy Efficient HPC Working Group 6<sup>th</sup> Annual Workshop

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EXPLORATION & PRODUCTION



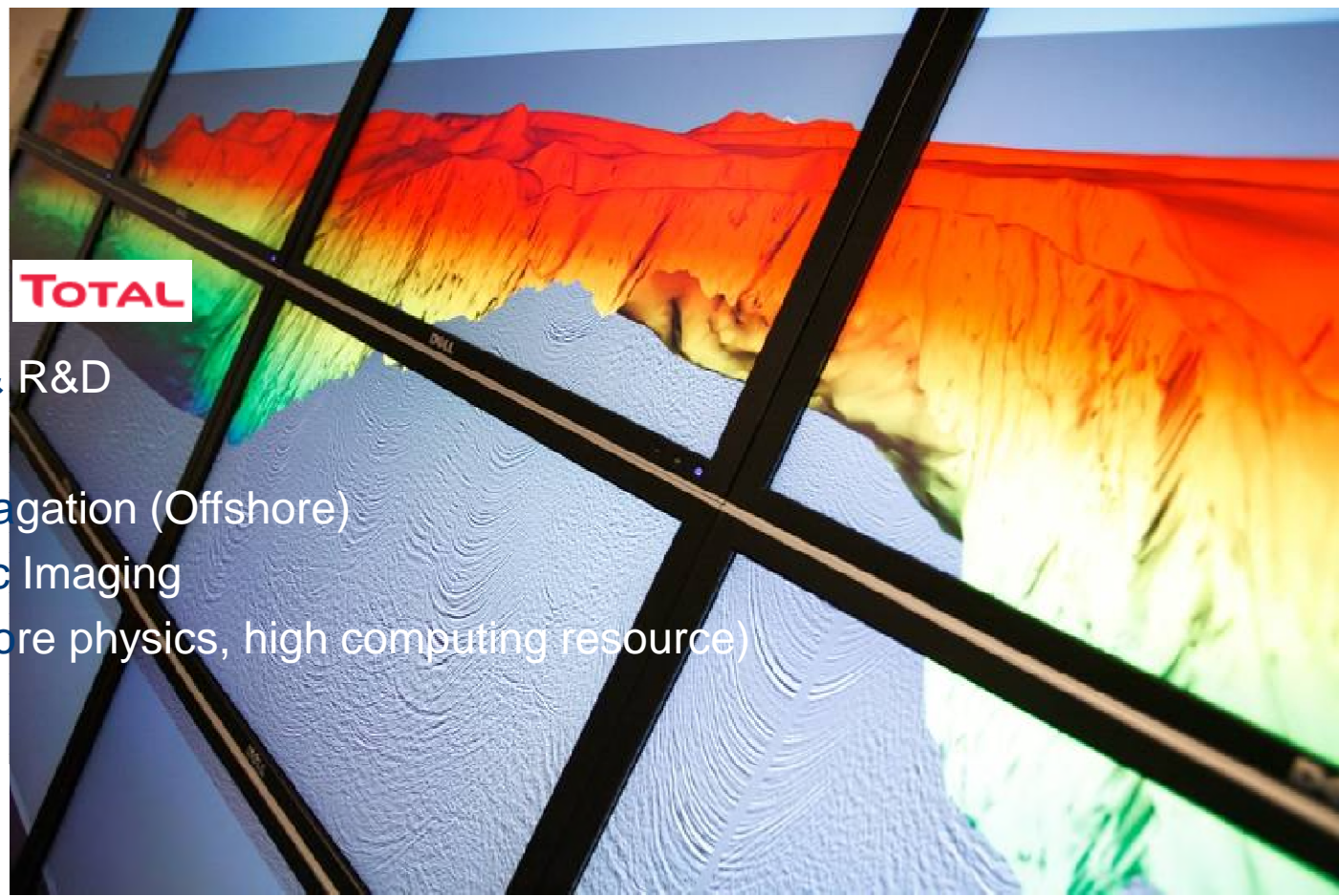


# AGENDA

## ❑ Earth Imaging: inside



- ✓ Global Operations & R&D
- ✓ Techniques
- ✓ Seismic Wave Propagation (Offshore)
- ✓ Quantitative Seismic Imaging
- ✓ Elastic Modeling (more physics, high computing resource)



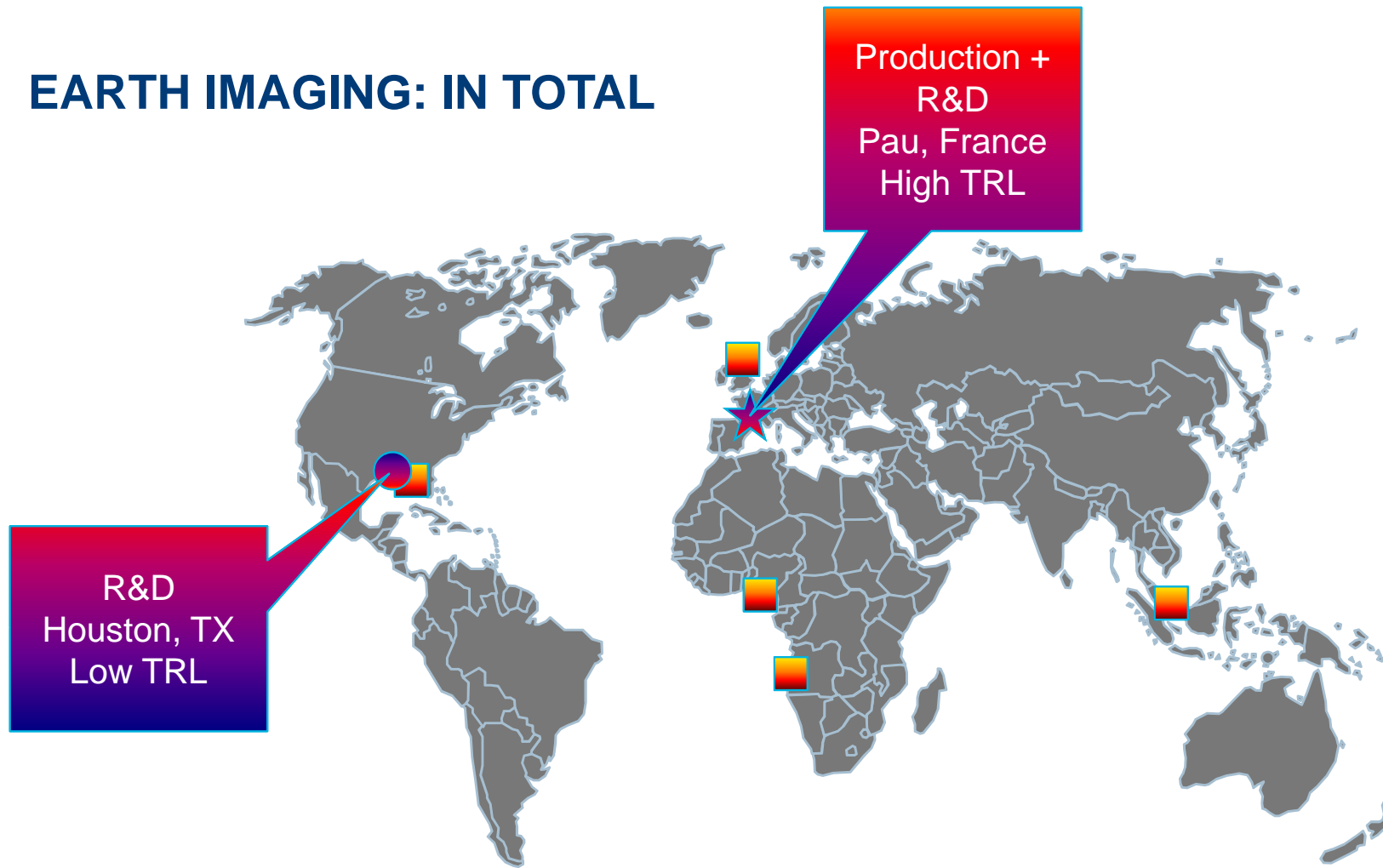
## ❑ HPC inside TOTAL

- ✓ Pangea & Laurentia 1.0 + Research Platforms
- ✓ Pangea 2.0, 3.0 + Expanded Research Platforms

## ❑ Cold as ICE

- ✓ Direct & Indirect Liquid Cooling
- ✓ Chiller with Ice Tray
- ✓ Heat Capture System

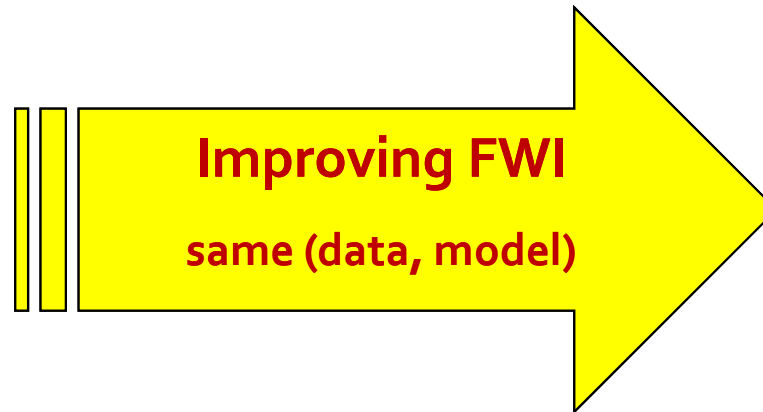
## EARTH IMAGING: IN TOTAL



- ★ HQ: Operations + R&D
- ▣ Operations/Hub
- R&D

- ✓ 5 Operations/Hubs
- ✓ 2 R&D Centers
- ✓ 100+ Imaging projects completed '13-'14

# EARTH IMAGING: QUANTITATIVE TECHNIQUES AND ALGORITHMS



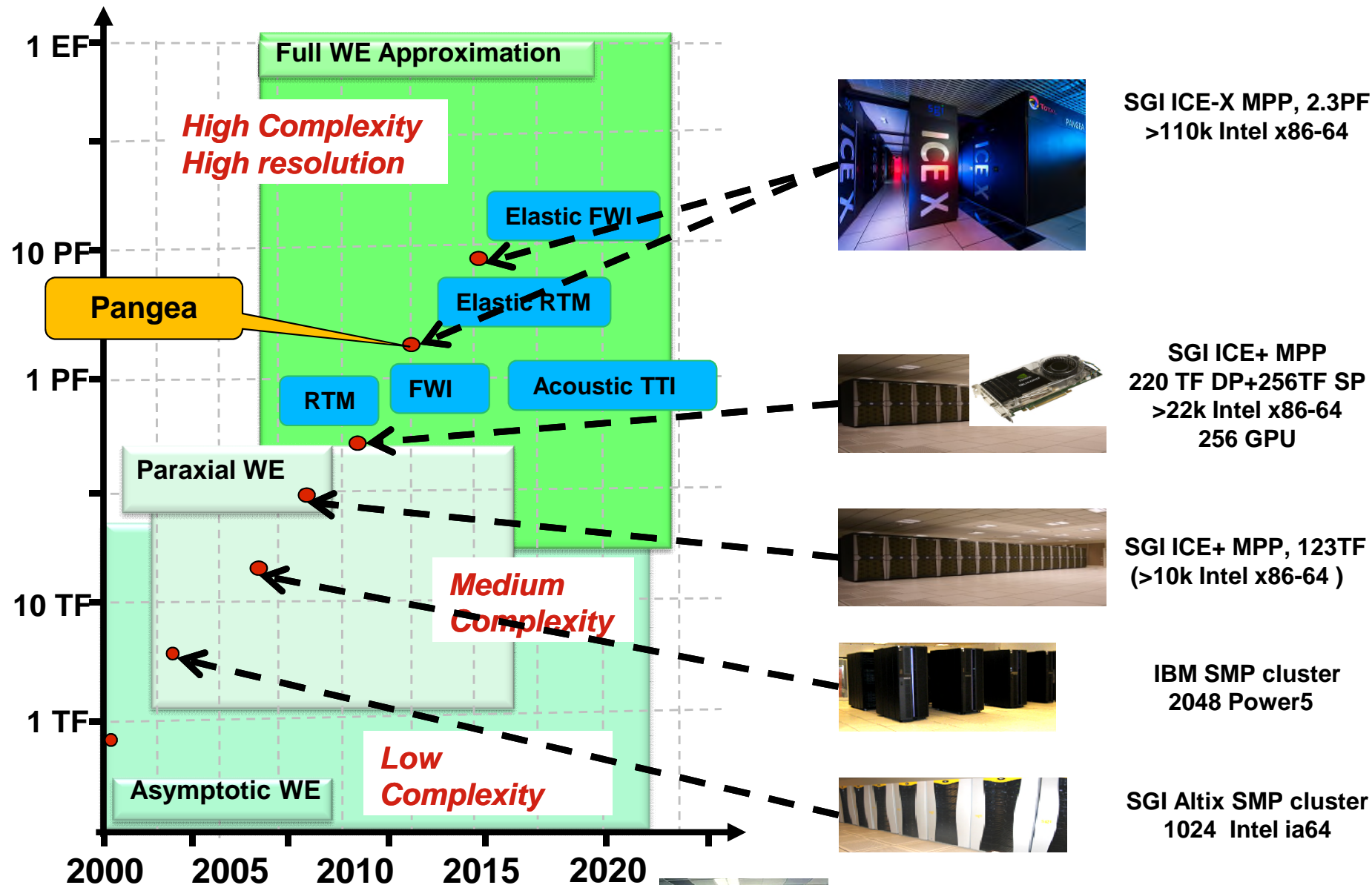
## No Visible Geological Features

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## Visible Geological Features

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# EARTH IMAGING: TOWARD FULL WAVE EQUATION



## HPC INSIDE TOTAL

| System      | FLOPs (PF) | Power (MW) | CPU (cores) | eHyper-cube | Ram (TB) | Scratch (PB/GBps) |
|-------------|------------|------------|-------------|-------------|----------|-------------------|
| Pangea 2012 | 2.3        | 2.4/1.7    | 110k        | 10D         | 440      | 17/300            |
| Pangea 2016 | > 6        | 4.8/3.4    | 220k        | 14D         | > 1,000+ | > 30/450          |

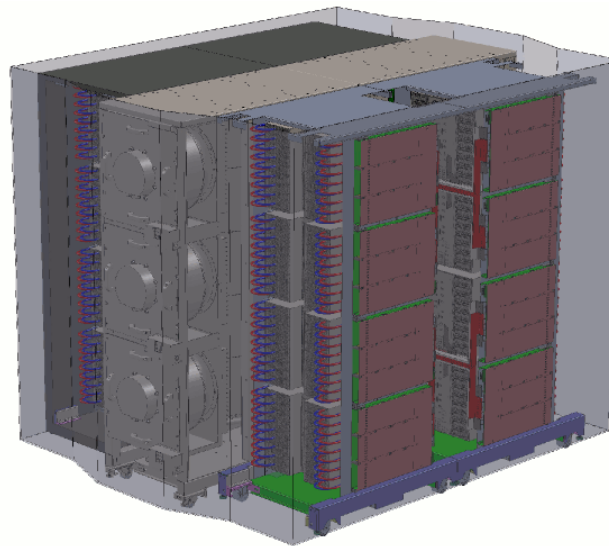
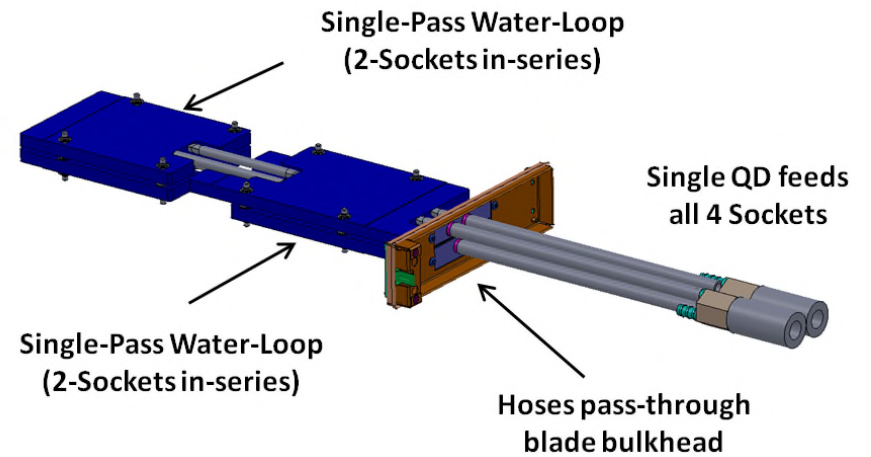
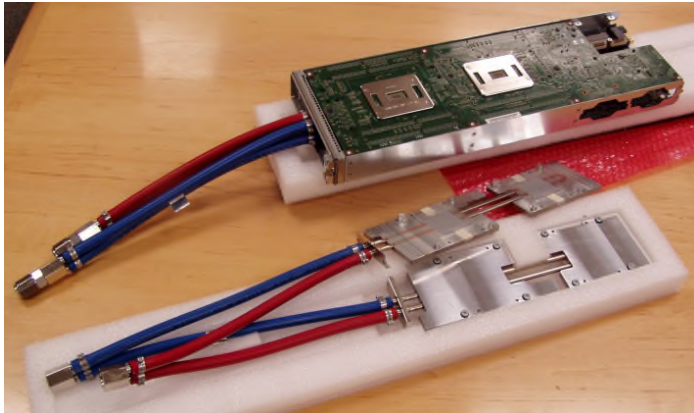


| RTM run-time             | 35 Hz    | 50 Hz    |
|--------------------------|----------|----------|
| HPC 2010 (Westmere)      | 30 days  | 120 days |
| HPC 2012 (Ivy Bridge)    | 2 ¼ days | 9 days   |
| HPC 2016 (Ivy + Haswell) | ½ day    | < 3 days |

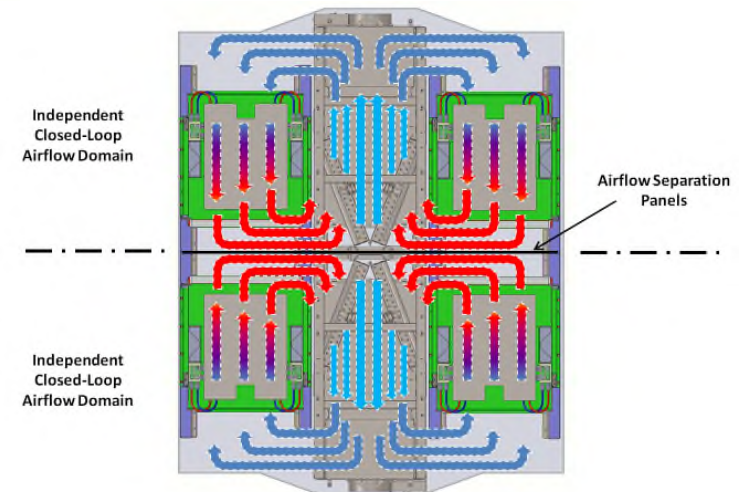




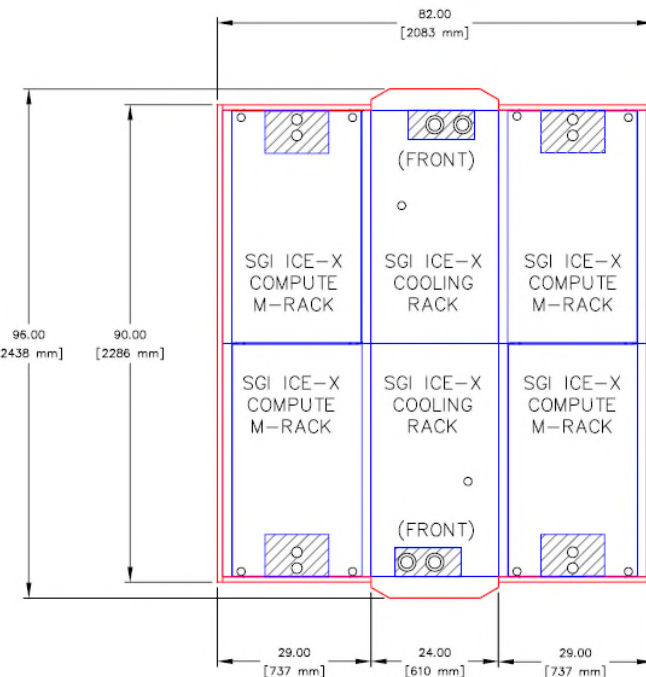
# DIRECT & INDIRECT LIQUID COOLING



**IVB: 9,216 cores/cell**  
**HSW: 13,824 cores/cell**



**IVB: 12 Cells (48 Racks)**  
**HSW: 8 Cells (32 Racks)**  
**20 Cells (80 Racks)**



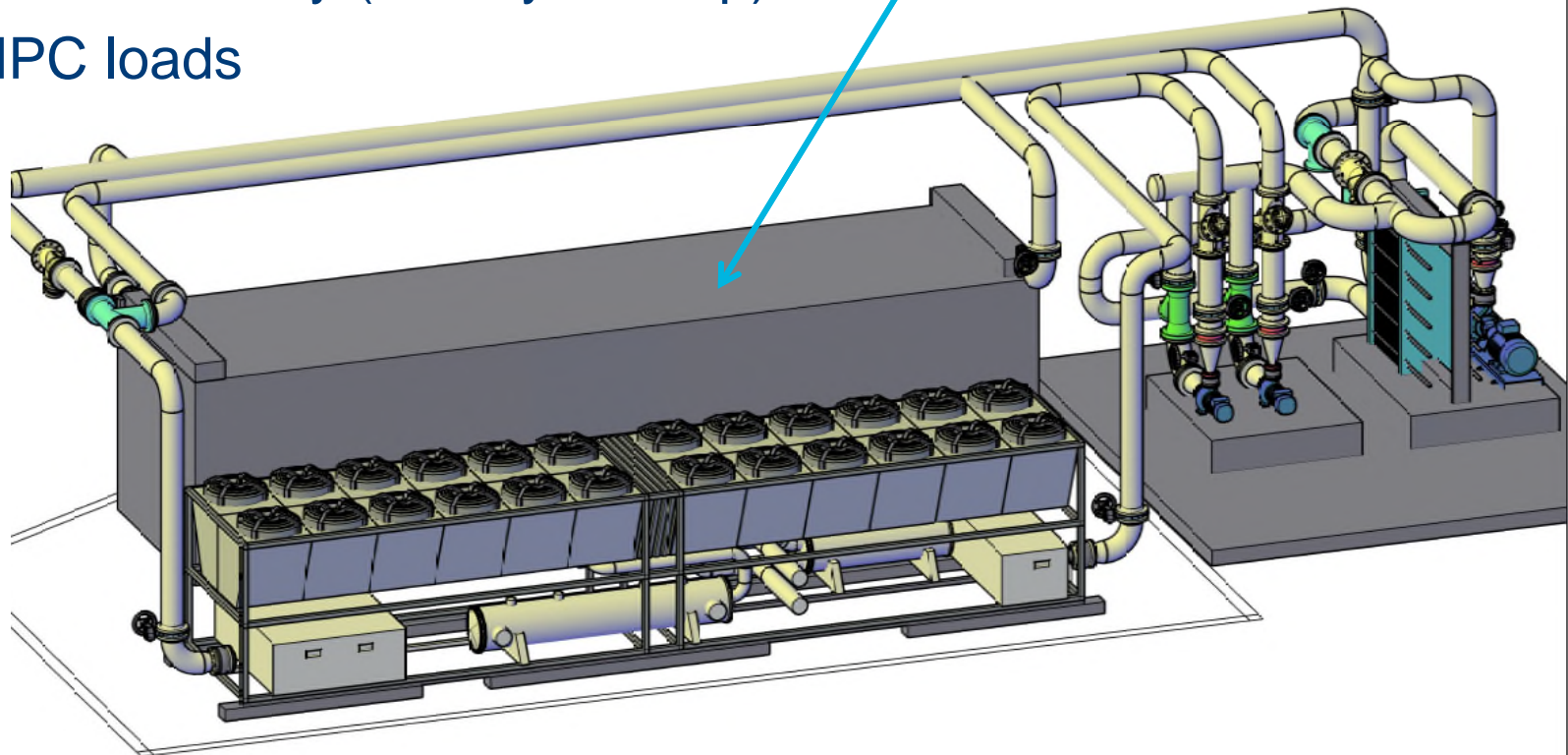
## CONSIDERATIONS FOR LIQUID COOLING

- ✓ Retrofitting air-cooled components
- ✓ System specific design specs
- ✓ Temps, delta-T, flow-rate, pressures
- ✓ Chemical treatments
- ✓ High thermals much quicker (tight packaging) in failure
- ✓ Makeup water
- ✓ Disposal of water (when flush is needed)
- ✓ Embrittlement (a word I never knew before) zinc reduction in brass
- ✓ MEP scope: Pumps, valves, tanks, lines, insulation, etc.
- ✓ Higher densities (both pro and con)
- ✓ Legionnaires' Disease (from bacteria) – large cooling infra.
- ✓ Difficult to detect small subfloor leaks
- ✓ **Good performance (1 DIMM per 55,000 per week)**



## ❑ Chiller with ice storage

- ✓ Reduces demand charges
- ✓ Cuts the top of consumption curve
- ✓ **4800 kWh**
- ✓ Increased reliability (tertiary backup)
- ✓ Non HPC loads



# Ice Storage

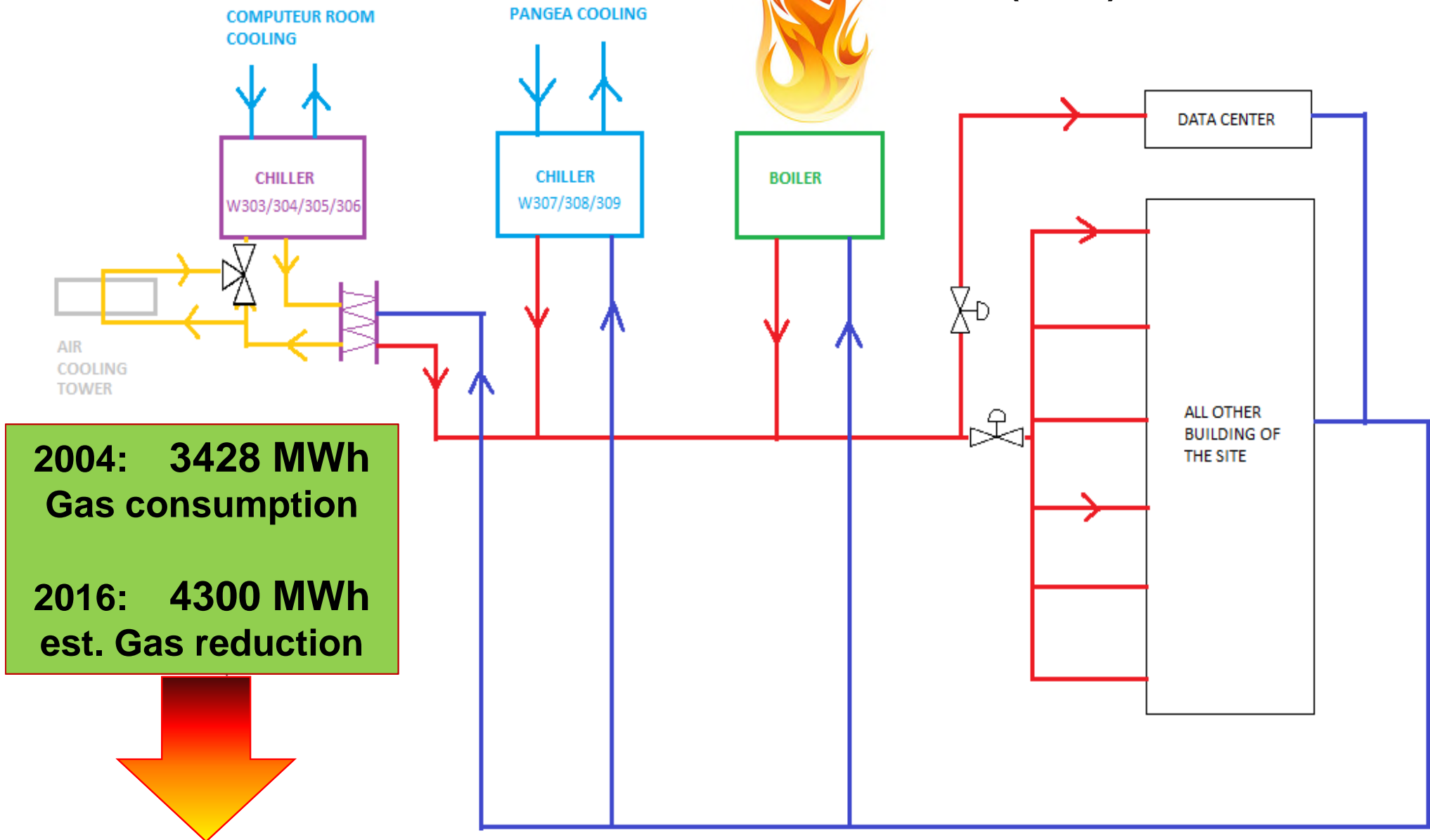


# Chiller



# HEAT CAPTURE SYSTEM

Used only  
when temps  
< 3 °C (37 °F)



# THANK YOU